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ABSTRACT

An alternative measure for evaluating the performance of academic departments was studied. A comparison was made with the traditional manner for computing unit costs and productivity ratios: prorating the salary and effort of each faculty member to each course level based on the personal mix of course taught. The alternative method used averaging of errors and input from an external group of peers. Differentially weighted student credit hours (DWSCH) were selected as the unit to be costed. In order to test the use of unit costs based upon DWSCH, cost estimates were prepared for 50 departments at a major research university using 5 years of data. Attention was directed to the stability of the ratios, psychometrics/uncertainty model, and a construct validation of the economies and efficiences of scale. The results of the analyses show that the weighted data provide significantly better measures of costs and productivity than the estimates produced by the traditional Information Exchange Procedures. In addition, the use of DWSCH produces a major reduction in the number of measures produced in the costing process. By reducing the number of measures produced, costing by operating department focuses attention on the resources to be allocated to an operating unit. (SW)

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An Alternative Method for Computing Unit Costs and Productivity Ratios

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THE ASSOCIATION FOR INSTITUTIONAL RESEARCH

This paper was presented at the Twenty-Fourth Annual Forum of the Association for Institutional Research held at the Hyatt-Regency in Fort Worth, Texas, May 6-9, 1984. This paper was reviewed by the AIR Forum Publications Committee and was judged to be of high quality and of interest to others concerned with the research of higher education. It has therefore been selected to be included in the ERIC Collection of Forum papers.

Daniel R. Coleman, Chairman
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An Alternative Method for Computing Unit Costs and Productivity Ratios

Abstract

Cost per SCH and SCH per FTE Faculty are frequently used indices for the evaluation of resource allocation by discipline and course level. The traditional manner for computing these indices is to prorate the salary and effort of each faculty member to each course level based on the personal mix of course taught. This procedure is complicated, expensive, and does not guarantee usable results. An alternative is demonstrated which uses averaging of errors and input from an external group of peers. The stability of this index is compared to the stability of the traditional indices for a major research university.

An Alternative Method for Computing Unit Costs and Productivity Ratios

Introduction

Unit cost measures represent a uni-dimensional index of the resource allocations made by management. Typically measures of cost use a single surrogate measure representing some portion of the outputs produced by the instructional process. In unit costing the typical procedure is to allocate cost to level of instruction. The procedure is to sum credit hours of instruction and divide by total costs (direct or indirect). In addition, all costing procedures ignore the impact of joint production in the instructional process. Cost accounting theory lacks a unique, theoretically correct procedure to allocate cost under conditions of joint production (Thomas, 1982). In the face of joint production and surrogate outputs, cost analysts make arbitrary allocations of costs to these surrogate outputs. Thomas (1930) provides an exhaustive analysis of the behavioral implications that occur when decision makers rely exclusively on arbitrarily generated cost estimates. He concludes that with imperfect procedures the results are misleading, incorrect, and potentially dangerous. From Thomas's research it is clear that decision makers should not make resource allocation (or reallocation) decisions exclusively on the basis of unit costs. If unit cost estimates indicate a significant disparity between or among operating units, a decision maker still needs to examine the factors that contribute to these differences.

Productivity ratios are another index used to evaluate the performance of academic departments. This ratio of student credit hours (SCH) taught by the unit divided by the FTE faculty teaching in the unit is also flawed by

the use of SCH as a surrogate for all of the outputs of the instructional process. At least the measure is easily obtained and can be readily displayed. McLaughlin (1981) raised significant questions about the appropriateness of using SCH to make inferences about faculty instructional effort.

Despite concerns raised by McLaughlin and Thomas the use of cost and productivity ratios have become a permanent part of the management of higher education. This paper looks at the generation of cost and productivity ratios and gives a way to calculate them that assures greater usefulness; as to virtue: caveat emptor (let the buyer beware).

In higher education most attempts to consider the department look at cost of instruction and productivity by level within an academic discipline. The Information Exchange Procedures (IEP) typify this approach. The IEP costing algorithms arbitrarily allocate the efforts and associated costs of individual faculty members to multiple levels of instruction within academic disciplines. The summation of these allocations over all faculty determines both unit cost and productivity. The intent seems to be to consider the differences in cost and productivity which are expected to occur by course level. However, academic administrators do not allocate operating monies and faculty positions to level of instruction within academic disciplines. At most universities, management allocates tangible resources to an operating unit (e.g., an academic department, school or college). Many, if not most, of the management information systems used in large universities will trace tangible allocations of both money and faculty positions to operating units. A clear focus on operating units appears to be essential if these indices are to support internal resource allocation decisions.

An Alternative Approach

Attempts to determine operating costs for an instructional department usually focus on the surrogate measure of the outputs of the unit under consideration. For this study, differentially weighted student credit hours (DWSCH) were selected as the unit to be costed (see Bloom, 1983, for an explanation of DWSCH). Bloom's analysis provides differential weights that convert upper level and graduate credit hours into equivalent lower division student credit hours units with different weights for each discipline division. The weights he provides are empirically determined and produce a normal or very nearly normal distribution of instructional productivity indices over a large sample of universities within discipline.

Using Bloom's differential weights leads to the simple calculation of an instructional department's unit costs and productivity. Equations 1 and 2 define the calculations.

$$\text{Unit Cost (i)} = \text{Total Direct Cost (i)} \;/\; \text{DWSCH (i)}. \qquad (1)$$

$$\text{Productivity (i)} = \text{DWSCH(i)} \;/\; \text{FTE Faculty (i)}\ . \qquad (2)$$

Where: Total Direct Cost (i) = direct expenditures in the ith instructional department.

DWSCH (i) = differentially weighted student credit hours produced by faculty teaching in the ith instructional department.

and

FTE Faculty(i) = FTE teaching faculty in the ith department.

In order to test the use of unit costs based upon DWSCH, cost estimates were prepared for 50 departments at a major research university using five years of data. Direct departmental expenditures were used to develop the unit costs. These expenditures included departmental operating expenses plus the salaries and and fringe benefits paid to faculty and staff assigned to the department. These expenditures were then adjusted to 1977 dollars using the Higher Education Price Index (HEPI) developed by Halstead (1983). In addition, productivity ratios were calculated for each department over the same time interval. Only instructional faculty were included in the productivity ratio calculations.

These indices were analyzed using techniques similar to the analysis of IEP cost and productivity estimates reported by McLaughlin, 1983. The results of these studies are reported in the following section.

Analysis of the Stability and Reliability of the Indices

Methodology

Three analyses investigate the characteristics of the indices from the weighted data. The first analysis is the more traditional investigation of stability of the ratios (reliability over time). The procedure recommended by Winer (1962) for rater reliability was used. This is equivalent to an intra-class correlation where the differences over years contribute to the error term. These stabilities were averaged using the Fisher 'z' transformation and plotted against time to obtain an estimate for the consistency of the indices (e.g., the estimated reliability for zero time

separation). The standard errors of measurement and prediction were calculated. The standard error of measurement (SEM) is used to make statistical statements about the true score given a raw score. The standard error of prediction (SEP) is used when one is considering predicting one raw score from another raw score.

The second part of the analysis involved the investigation of psychometric characteristics of the indices. In this analysis the absolute difference of adjacent years was compared to the average of those two years. This ratio of |diff(x)|/(average x) was regressed on department size as measured by size of faculty. This analysis is suggested by the work done by Kline and McClintock (1953) who developed equations for uncertainty in single sample experiments.

The third part of the analysis involves regressing the indices on the size of the departments as measured by the number of instructional faculty. Previous work has argued that "economies of scale" are muted by the complexity of a university as measured by the number of departments and the offering of advanced degrees. This investigation of economies of scale represents a construct validation of Bloom's weights. If the weighting system accurately compensates for the lower productivity of departments engaging in advanced instruction, and if in fact economies of scale exist, then the cost per DWSCH should go down and possible the productivity should go up as the size of departments increase.

Results

Tables 1 and 2 summarize the results of the analysis. The mean productivity of the 50 departments ranges from 778 to 831. The standard deviations for productivity range from 240 to 324. The stability of the

productivity ratios ranges from the .90's for adjacent years to .54 for the five year spread from 1977 to 1982. The standard error of measurement ranges from the high 50's to about 200 for the spread of 1982 to 1977. These results are shown in Figure 1 along with the error anticipated in predicting one year from another (assuming the model is correct). The standard error of prediction (SEP) is related to the SEM by:

SEP = SEM * sqrt(1+Reliability)

Estimates of the consistency of the indices can be obtained from this figure by extrapolating the curves to the zero point for the separation scale. This estimates the consistency of the productivity index to be about .95 to .96 with a SEM of 65 and a SEP of about 75.

The downward decaying curve for absolute mean difference (AMD) in Figure 2 shows that there is a reduction in the error of adjacent years as a function of the size of the instructional faculty. This curve is given by:

AMD = .0633/(1 - .8785*e**(-.0549*average FTE Faculty))

(r=.365, p<.001)

The curve shown in Figure 3 supports the belief that efficiencies of scale can be found at the departmental level when weighting factors are used to take level of instruction into account. This curve is given by:

Productivity = 961.1/(1+1.1256*e**(-.121*average FTE Faculty))

(r=.482, p<.001)

This relationship implies that productivity in an instructional department is related to the size of the department.

The mean unit costs of the 50 departments range from 40 to 48 dollars per DWSCH. The standard deviations for unit costs range from 21 to 27. The stability of the unit cost ratios ranges from the .90's for adjacent years

to .51 for the five year spread from 1977 to 1982. The standard error of measurement ranges from below 10 to about 18 for the spread of 1982 to 1977.

Figure 4 illustrates the relationship of unit cost calculations based upon DWSCH to departmental size as measured by FTE faculty. This curve is given by:

Unit Cost = 34.98/(1-.7144*e**(-.0969*average FTE Faculty))

(r=.455, p<.001)

This relationship also supports the assertion that economies of scale exist at the departmental level. It should be noted that the relationships of efficiencies and economies of scale are not perfect. This analysis indicates that productivity ratios for the weighted data continue to improve rapidly until about 20 FTE faculty members are involved. However, Figure 4 suggests that most of the economies of scale appear to be reached at the departmental level when 10 FTE faculty members are traced to the department. These relationships deserve additional analysis. Figure 5 illustrates the curve for AMD in cost ratios for the weighted data and is analogous to Figure 2 for productivity ratios. This curve is given by:

AMD = .0478/(1 - .7872*e**(-.0174*average FTE Faculty))

(r=.291, p<.001)

As with the relationships with FTE faculty for economies and efficiencies of scale, the curve for costs is less dramatic than the curve for productivity. Figure 6 illustrates SEM and SEP for the cost ratio data. These standard errors are low, ranging from below 10 to the high teens. They also are less than the means for unit costs by a multiple of two or three.

Figure 7 illustrates the stability of both cost and productivity ratios. As noted before, this curve is based on actual points for the separations of one to five years. The point for zero separation is inferred by graphic interpretation.

Table 1

Means and Standard Deviations for Cost and Productivity Ratios

Year	Costs		Productivity	
	Mean	SD	Mean	SD
1977	40.64	21.80	798.70	261.63
1978	44.51	20.23	812.33	240.48
1979	45.52	23.37	777.69	254.14
1980	44.94	23.13	817.57	270.48
1981	44.83	26.51	830.08	291.85
1982	48.41	27.88	812.45	324.90

Table 2

Stabilities, SEM and SEP for Costs and Productivity Ratios

Separation	Costs			Productivity		
	Stability	SEM	SEP	Stability	SEM	SEP
0	.950	5.2	7.3	.960	60.0	84.0
1	.926	7.3	10.2	.915	82.2	113.8
2	.865	9.1	12.4	.840	112.9	151.9
3	.772	11.5	15.3	.768	133.0	177.7
4	.690	13.7	17.8	.665	162.8	209.9
5	.506	17.8	22.2	.537	200.2	248.0

Discussion

This investigation of an alternative way to compute cost and productivity ratios has used three major approaches: stability of the ratios, psychometrics/uncertainty model, and a construct validation of the economies and efficiencies of scale. The results are supportive for the future investigation and use of the procedures we have proposed. In

traditional stability of the ratios approach, reliabilities are good, ranging from consistencies of .95 to five year stabilities of about .5. The standard errors are about 1/4 the means in the traditional two-year period used for most planning. The distributions are fairly robust with means at least two times the standard deviations.

In the second approach (psychometrics/uncertainty model) we found that the absolute mean differences do in fact go down as the size of the department increases. While the correlations of these relationships are not large, they are significant. More work needs to be done with the weights and the procedure to see if some of this error variance can be explained with alternative weights or alternative procedures.

In the investigations of economies and efficiencies of scale (the third approach), the relationships are also significant and stronger with correlations of about .4. We take these results to reinforce both the concept of economies of scale when complexities are considered and also to validate the weights which were used to obtain the indices.

Student credit hours by discipline and level, FTE faculty and total direct expenditures are tangible products or resources traced to the department. The alternative used in this analysis replaces the arbitrary allocation of resources to level of instruction with the arbitrary conversion of multiple levels of instruction by discipline into equivalent units. The use of differentially weighted student credit hours (DWSCH) as the fundamental unit of production represents an arbitrary surrogate for a set of outputs of the instructional process. Like all other costing algorithms, the alternative method used in this analysis does not factor in all of the implications of the joint production of instruction and research. This method does, however, differ from the typical IEP approach in that the

output of an instructional department as measured in DWSCH is assumed to be the the co-product of all of the faculty teaching in the department. The approach differs markedly from the assumption in the IEP costing algorithm that the output of a department is merely the sum of the actions of individual faculty. In this regard, the methods used in this paper reflect modern systems theory which asserts that the output of complex socio-economic systems is distinctly different from the sum of the outputs of the constituent parts (Sutherland, 1975).

The results of our analyses show that the weighted data provide significantly better measures of cost and productivity than the estimates produced by the IEP algorithm (McLaughlin, 1983). In addition, these measures can be generated from standard university information sources without incurring the costs associated with the IEP costing approach. The use of standard university information resources also provides a reasonable audit trail for the costing process.

This analysis makes no attempt to examine the validity of these productivity and cost estimates for inter-institutional comparisons. In fact, no analysis has ever validated a costing procedure which generates comparable cost estimates for complex research universities. The use of differential weights should be examined to determine if inter-institutional comparisons based upon these surrogate units represent an improvement over the IEP approach.

The use of DWSCH as surrogate outputs produces a significant reduction in the number of measures produced in the costing process. In most major research institutions, decision makers are inundated with quantitative measures. A typical application of the IEP costing process can produce over 400 measures of cost and productivity. With this level of disaggregation,

decision makers have so much data that synthesis of its significance becomes nearly impossible. By reducing the number of measures produced, costing by operating department focuses attention on the resources to be allocated to an operating unit. The relative simplicity of the alternative approach suggested in this paper makes it possible for decision makers to evaluate the consequences of their decisions. Since cost estimates are uni-dimensional measures, resource allocation decisions should never be made solely upon the basis of unit costs.

Every attempt to develop unit cost and productivity estimates eventually resorts to an arbitrary choice of the surrogate output to be used as the fundamental basis of analysis. The main advantage of the alternative approach suggested in this paper is its simplicity. Since every approach is arbitrary and produces uni-dimensional measures, it would appear prudent to select costing algorithms which do not incorporate arbitrary allocations with costly data processing requirements and complex detailed analysis. This caveat should be especially important when the simpler methods produce measures which have superior reliability and stability.

STANDARD ERRORS OF PRODUCTIVITY RATIOS VERSUS DATA INTERVALS

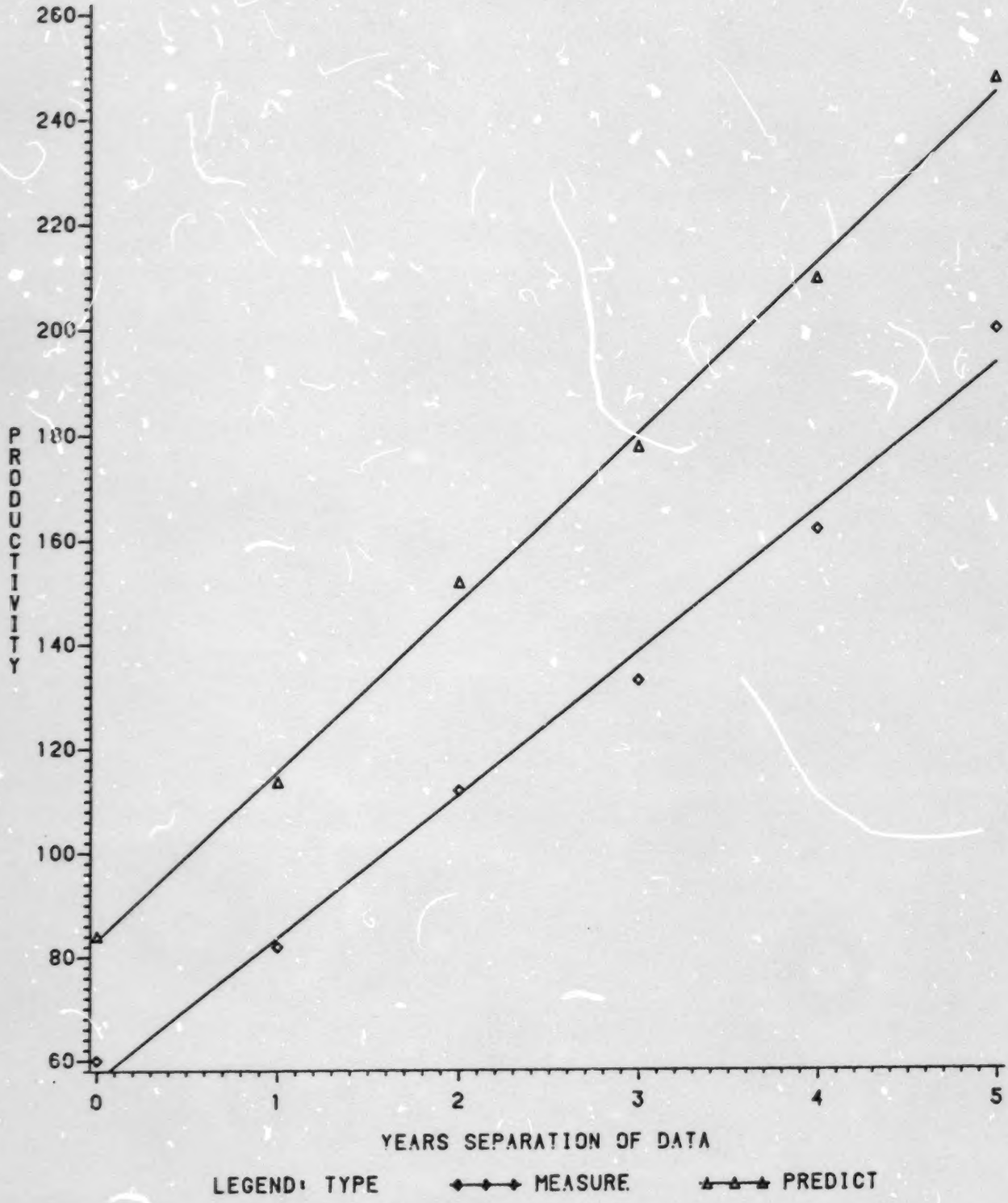

Figure 1

RELATIVE ABSOLUTE DIFFERENCE IN WEIGHTED STUDENT CREDIT HOURS PER FTE FACULTY VERSUS AVERAGE FTE FACULTY

MODEL: $y = a / (1-be^{-cx})$

$r = 0.37$

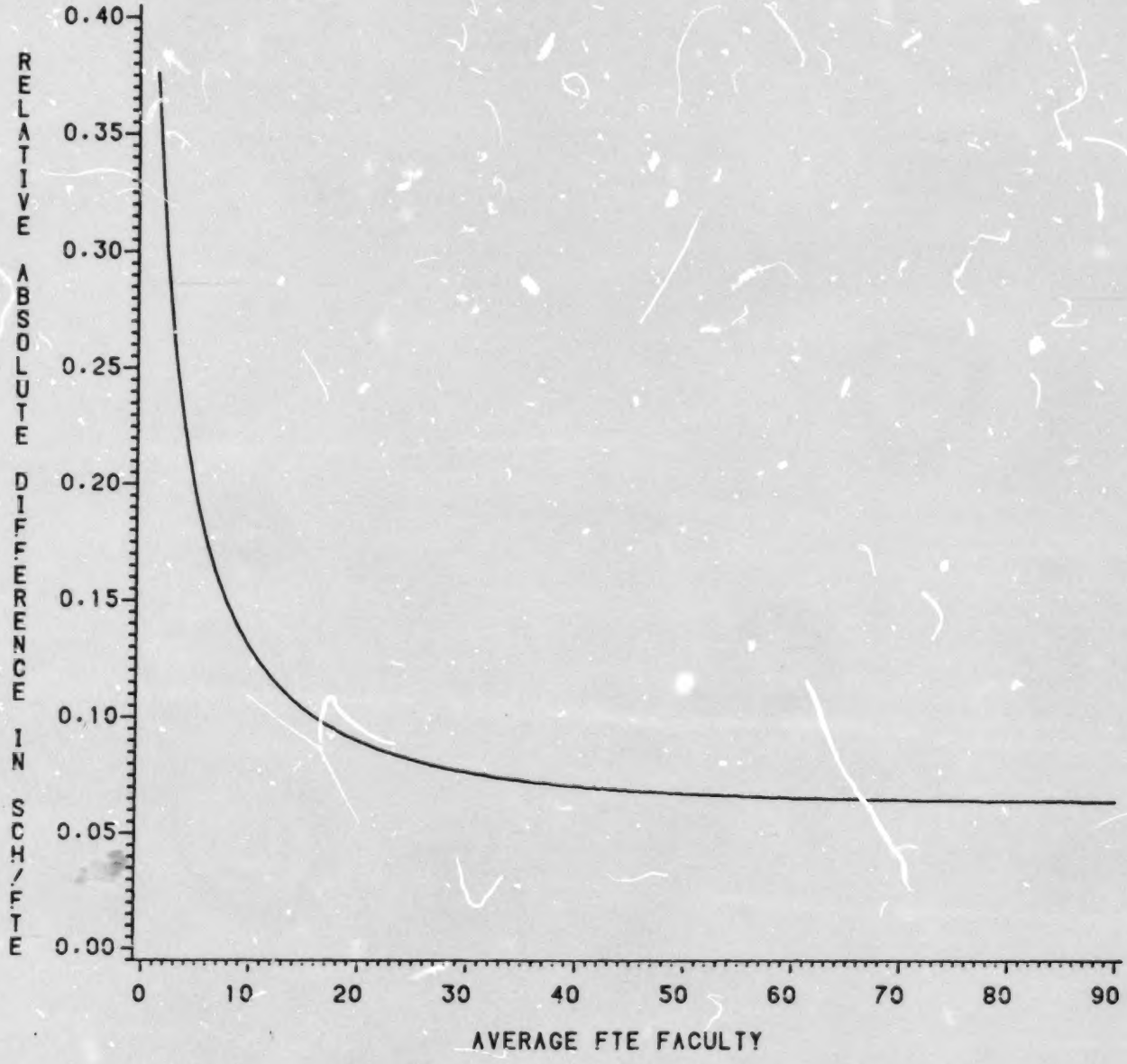

Figure 2

PRODUCTIVITY RATIO VERSUS FTE FACULTY

MODEL: $y = a / (1-be^{-cx})$

r = 0.49

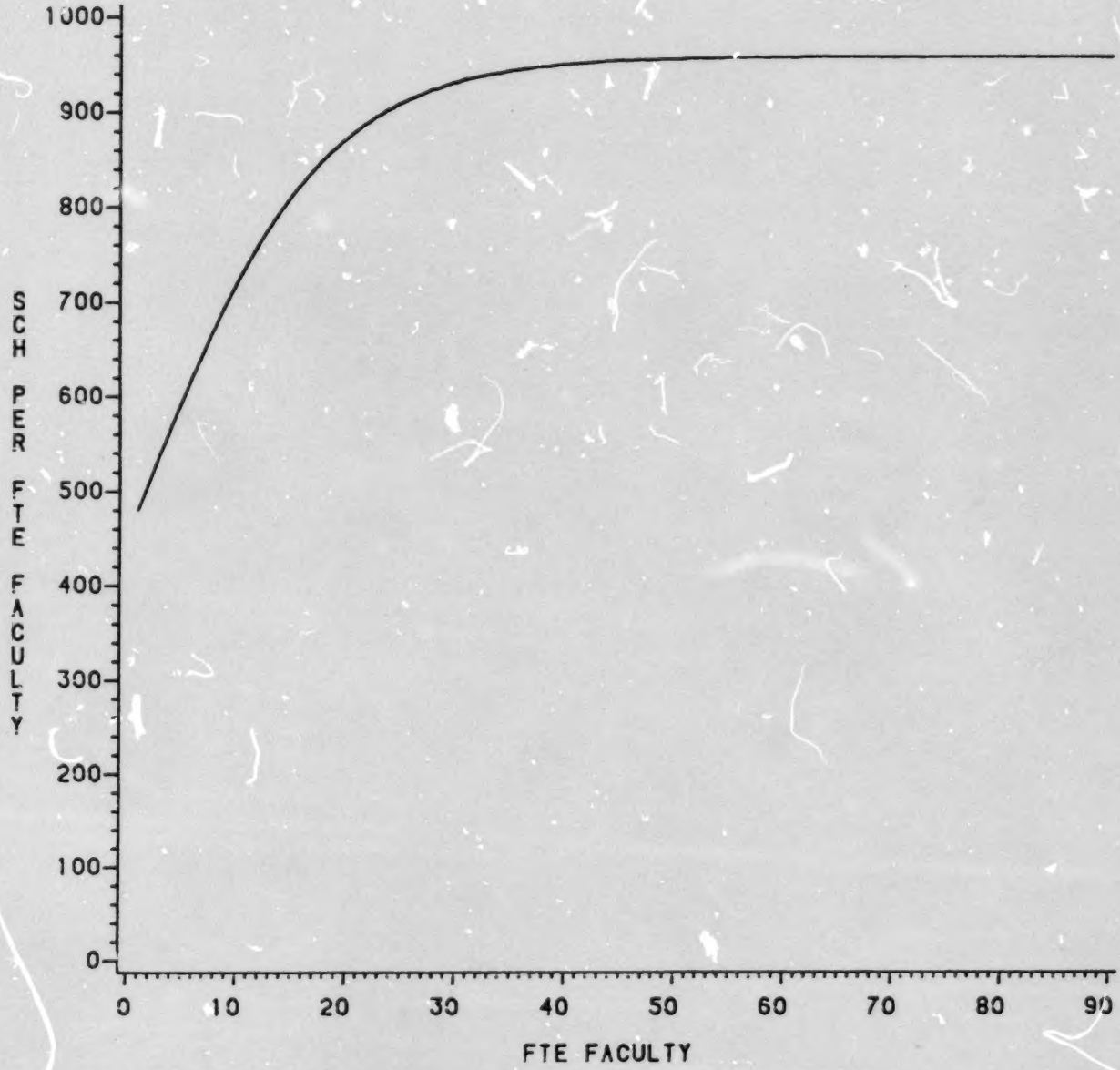

Figure 3

COST PER WEIGHTED STUDENT CREDIT HOUR VERSUS FTE FACULTY

MODEL: $y = a / (1-be^{-cx})$

r = 0.46

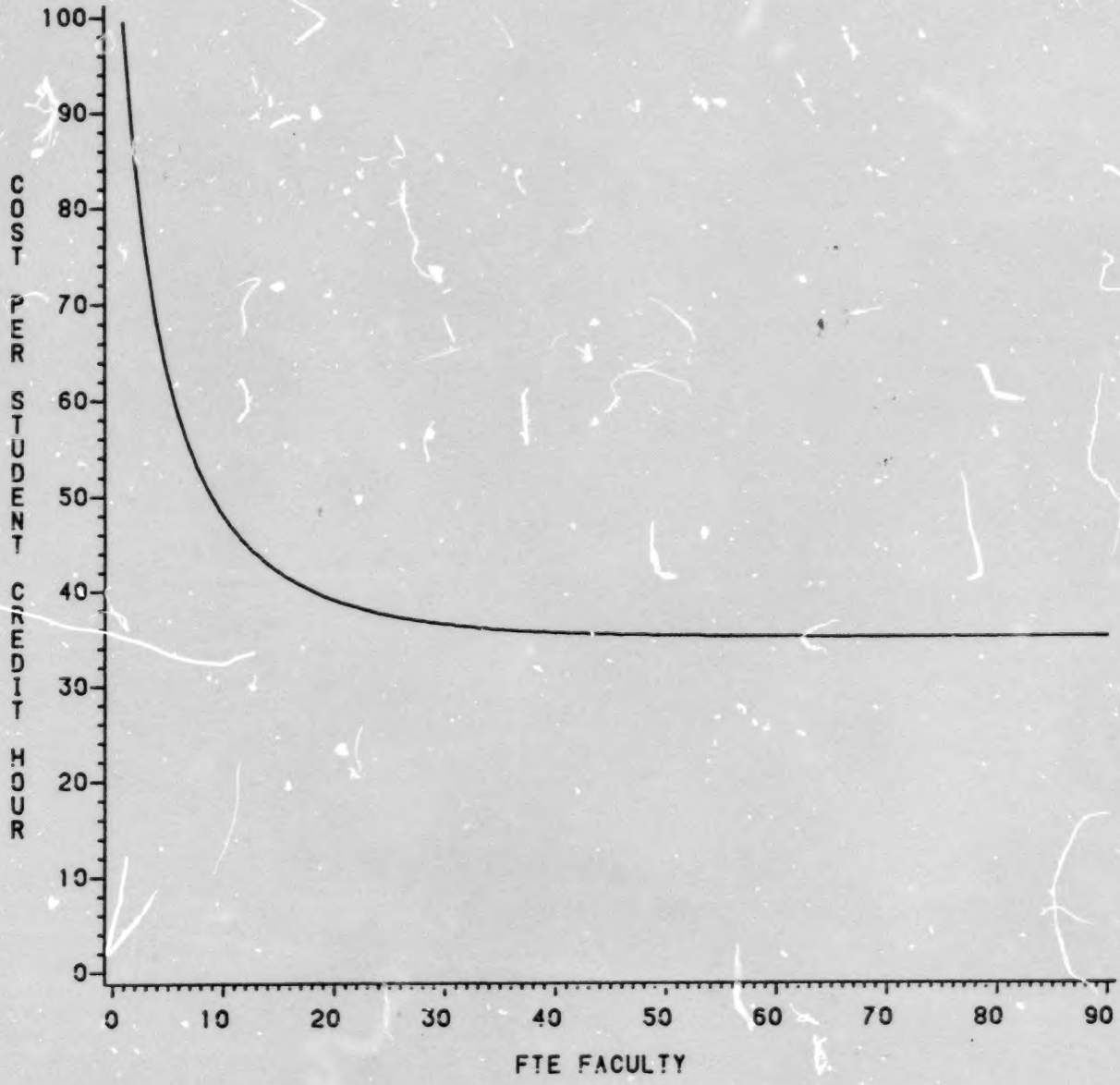

Figure 4

RELATIVE ABSOLUTE DIFFERENCE IN COST PER WEIGHTED STUDENT CREDIT HOUR VERSUS AVERAGE FTE FACULTY

MODEL: $y = a / (1-be^{-cx})$

r = 0.29

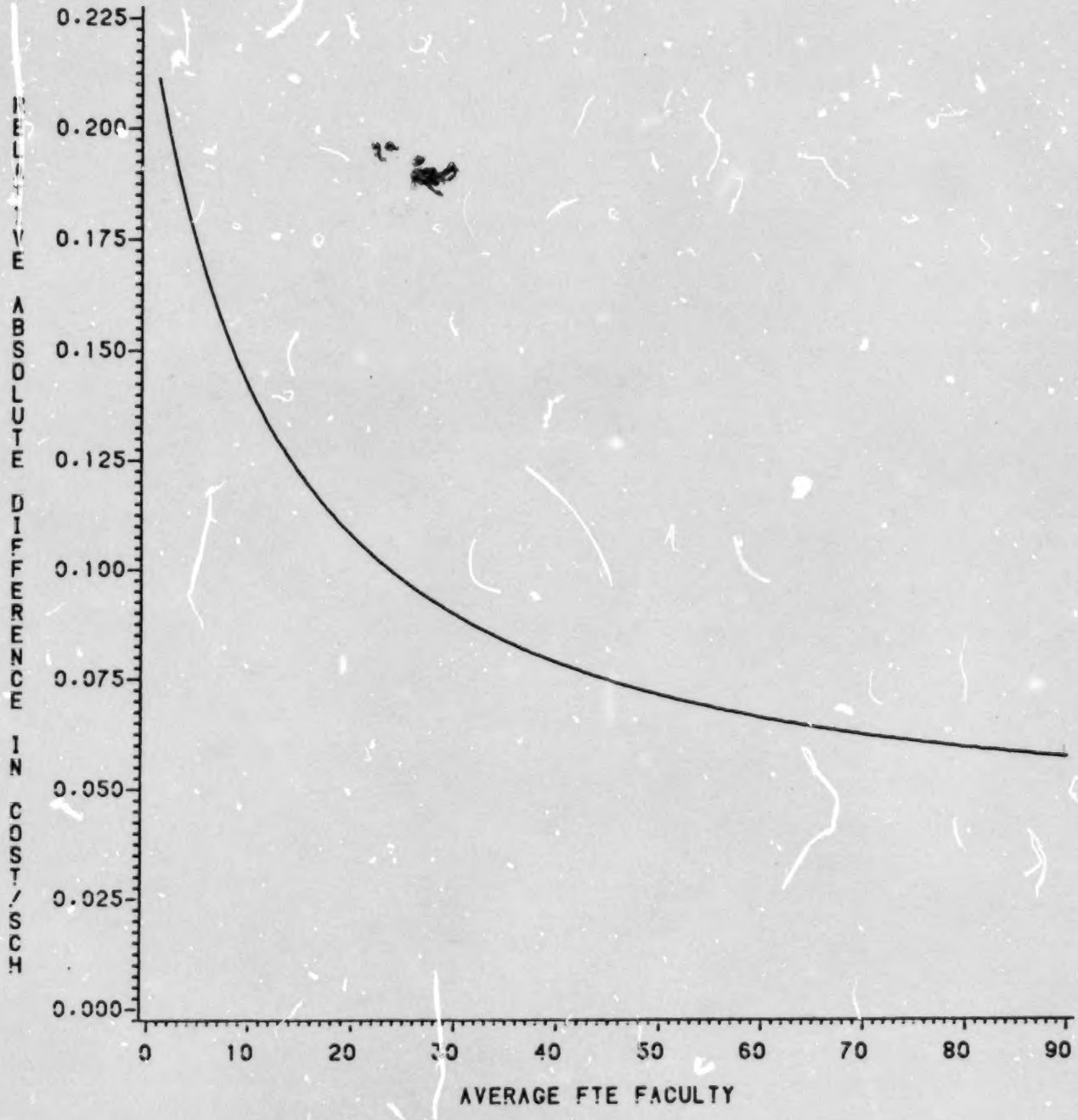

Figure 5

STANDARD ERRORS OF COST RATIOS VERSUS DATA INTERVALS

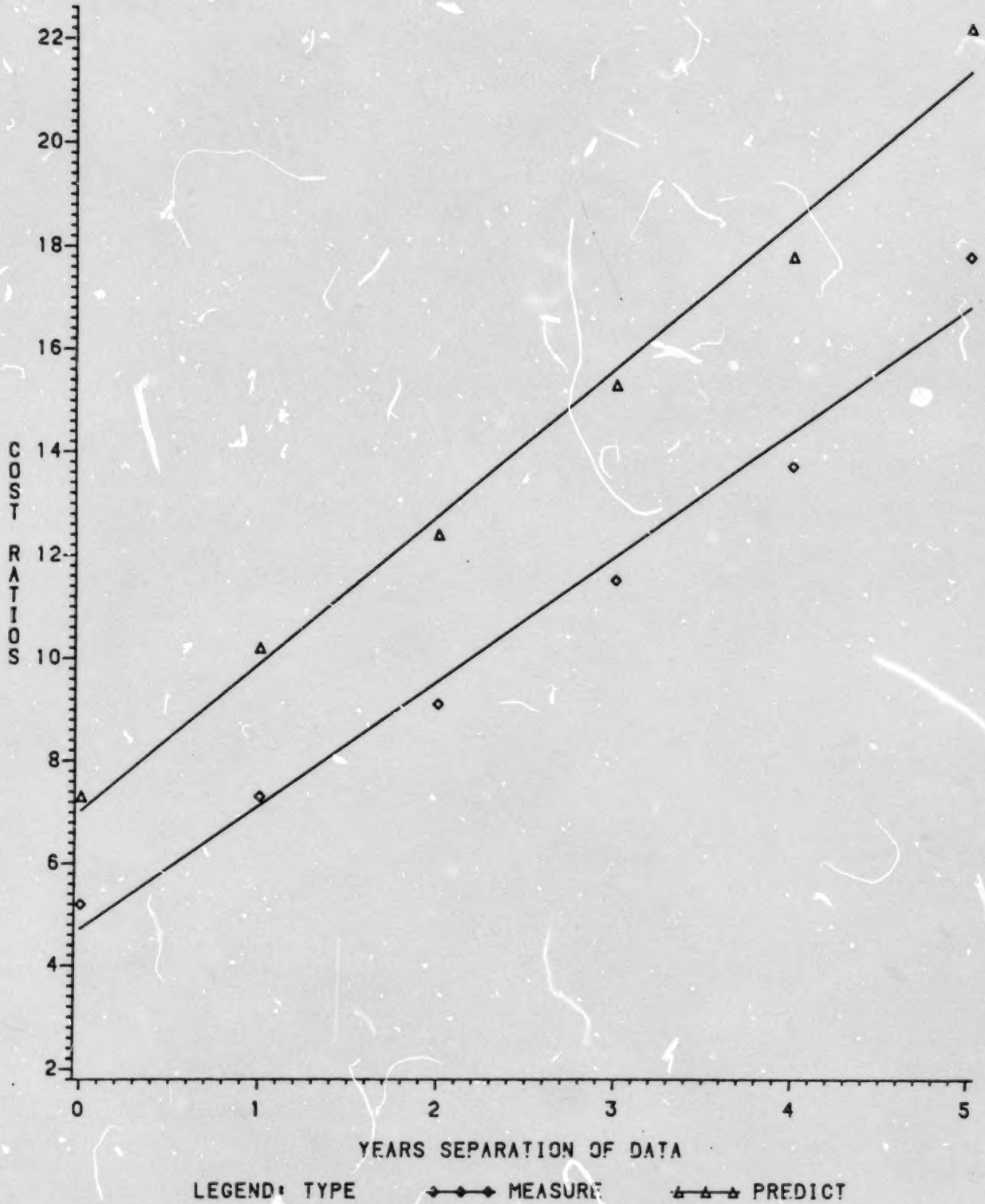

Figure 6

STABILITY OF PRODUCTIVITY AND COST RATIOS VERSUS DATA INTERVALS

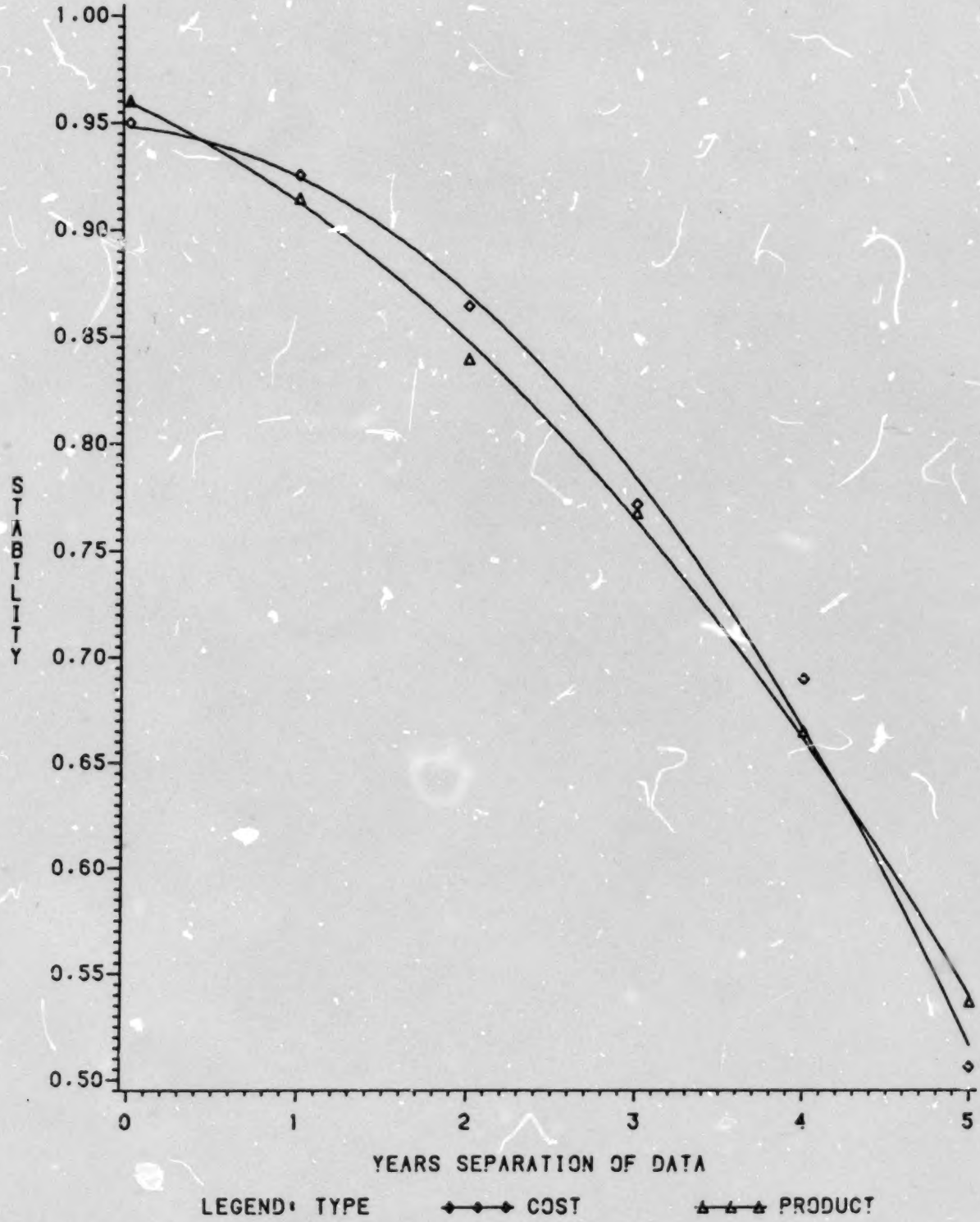

Figure 7

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